

THE STUDY OF AVIATION ACCIDENTS OF F-104 IN TAIWAN FROM PERSPECTIVES OF HUMAN FACTORS BY GREY SYSTEM

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This study took Grey System theory to probe the incidents/accidents of F-104 jet fighter within its service period in Taiwan. This analysis classified the essence of F-104 jet fighter mishap records by content analysis into machine failure and six different major human errors, such as skill, rule, knowledge, communication, judgment, leadership, that affecting to flying safety. In the mean time, owing the constrain of limited data quantity and distribution pattern uncertainty after divided into fine mishap details, the mathematic statistics method cannot handle the variables and relationships among variables effectively, the essence of Grey System theory needs no huge data quantity and specific distribution pattern. Thus, use the correlation analysis of Grey System can lead seven failures of flying mishap to reach the correlation coefficient. The aims of this survey are to investigate the nature of human error and understand potential elements that harm pilots, crew and aviation organization.

Introduction

German civil aviation engineer Meier Muller conducted an aircraft accident study in 1940 and found out that human factor took up more than seventy percent on the aircraft accidents and incidents. After sixty years later, all of aircraft accident statistics conducted by the International Civil Aviation Organization (ICAO), aircraft manufacturers, civil aviation authorities of different nations, and human factor specialists showed that human factor is the major one among all. Thus human factor can be considered the leading factor of all time, and the reason why this study is generated.

Flight safety is the ultimate goal ever since the beginning of aviation activities was launched. During the early stage, "Blood Priority" is based on some traumatic event has to occur in order true change take place, and redundant fail-free design was generated. All these efforts are pursuing the reduction of accident rate.

Up to now, the flight line, maintenance units, air traffic control units, meteorological units, etc. construct the complicated aviation activities. Human factor is still taking up the highest percentage of accident rate. Reviewing the accident cases of the past, the so-called "human factor" is preventable and avoidable, such as pilot error, negligence, poor judgment, air traffic controller error, maintenance crew error, airfield maintenance error, poor communication, etc. Thus, the methodology of this study is undertaking as following:

1. Take the human factors engineering theory as the foundation to study the essence of human factor within the Air Force accident/incident, and go through the content analysis to classify the flight safety record of Taiwan F-104 jet fighter. Base on "Crew Resource Management" theoretic study to examine how aviators, flight line working groups, and aviation organizations might cause
2. Potential threatening factor toward the flight safety.
3. Study the relationship between flight accident, incident and human error of Taiwan F-104 jet

fighter during its service period. Take the study result generated by "Grey System Theory" to pin point different human error might cause how serious different affect toward flight safety.

In this study, the aircraft accident focused on human factor and machinery failure. James Reason, in his book, Human Error, defines human error as, "any human activity that fails to accomplish the intended outcome" (Reason, 1991). Thus, in flight safety occurrence, "human error" can be defined as "Due to related personnel did not perform his/her job which consist of decision making, act and/or a decision did not made correctly within aviation systems and result in aircraft danger, incident, and/or accident." In addition, Reason (1994) and Jensen (1995) conducted a human error study and analysis, at pilot and flight team levels and from crew resource management viewpoint, human error can be divided into two categories, personnel factor and group factor, and each category contains three human error levels as following:

- A. Personnel factor: skill, regulation, knowledge.
- B. Group factor: communication, judgment, leadership.

In order to find out the probable causes of F-104 major mishap, this study divided aircraft mishap into three categories and weighted & redefined as following:

1. Major accident: the mishap resulting in human lives loss and/or aircraft destroyed completely was weighted 600.
2. Minor accident: the mishap takes eight hundred direct labor hours to repair and/or maintenance toward the aircraft was weighted 60.
3. Incident: the mishap takes less than eight hundred direct labor hours to repair and/or maintenance toward the aircraft was weighted 20.

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Though the Air Force F104 is the data source of this study, all statistic theory application can be used to provide aviator training systematically in order to build up flight safety knowledge they should have. In addition, to educate aviator to prevent error from happening and develop a suitable standard operation procedure; most of all, enable aviator foresee what kind of error might take place when they are facing abnormal situations; knowing how to correct the error between its initiative stage and ending stage, and making full use of all software and hardware resources to complete their missions successfully and safely.

Content Analysis

At the early stage of "content analysis" was focused on the information of mess media, especially to those written form information published on newspaper or magazine. With the progress of the analysis method, the "content analysis" is not only applying to other social and human sciences' fields now but also becoming a major method of data analysis. Though "content analysis" is based on "quantified" analysis processes, it does not mean it's purely a quantitative analysis only. The essence of this approach is analysis the change of the quantity of the content then assuming the change of its essence. Thus this analysis takes quantity and essence as the same weight. In additions, this approach systematically sorted, statistic, and quantitative analysis all contents of official documents and papers of major mishaps which issued in written form by the Taiwan Air Force during the past twenty years. These data is suitable perfectly for content analysis to study and explore.

Grey System Theory

Grey system theory is focusing on uncertainty, data incompleteness of the system model, and conducting relevance analysis, model construction, via forecasting and decision making to explore and understand system. The grey theory, first proposed by Prof. Deng, avoids the inherent defects of conventional, statistical methods and only requires a limited amount of data to estimate the behavior of an uncertain system. During the past two decades, with hard work by scholars, the grey theory has been successfully applied to research in industry, social systems, ecological system, economy, geography, traffic, management, education, environment etc. To sum up, the main purpose of the grey system theory focuses on the relational analysis model construction, and circumstances such as: no certainty, multi-data input, discrete data, and insufficient data through predicting and decision-making.

Grey Relational Analysis is an impacting measurement model, which takes the measurements of relations that change in two systems or between two elements into the system in time. The basic concept of grey Relational grade: the mathematical function of grey relational grade can be described as follows:

The Comparison of Sequence.

Assume a sequence as

$$X_i = [X_{i,1}, X_{i,2}, \dots, X_{i,k}] \in X_i$$

$$i, 0, \dots, m, k, 1, \dots, n \in N, \text{ and meets the}$$

following three conditions:

- Non-dimensional: Factors must be processed to become non-dimensional, irrespective of its measured unit.
- Scaling: The value $X_{i,k}$ of each sequence X_i belongs to the same order (order difference cannot be greater than 2).
- Polarization: Factor description of sequence should be in the same direction.

Thus, this sequence is said to be comparable.

Deng's Grey Relational Grade

Using traditional methods, Deng had derived the first Grey relational grade formula by meeting all four axioms, which is primarily divided into two parts:

$$X_0, k, X_i, k, \frac{\Delta_{\min} + \xi \Delta_{\max}}{\Delta_{0i}(k) + \xi \Delta_{\max}}$$

where

- $i, 1, 2, 3, \dots, m, k, 1, 2, 3, \dots, n$.
- X_0 : Reference sequence, X_i : Inspected sequence.
- $\Delta_{0i} = X_0, k - X_i, k$: The difference between X_0 and X_i . Norm.
- $\Delta_{\min} = \min_i \min_k X_0, k - X_i, k$.
- $\Delta_{\max} = \max_i \max_k X_0, k - X_i, k$.
- ξ : Distinguishing coefficient, and $\xi \in [0, 1]$.

Grey Relational Grade: The mean of Grey relational coefficient

$$X_i, X_j, \frac{1}{n} \sum_{k=1}^n X_i, k, X_j, k.$$

In addition, Grey relation indicates the relational grade of two sequences. The values of the sequences are the vital information. Thus, take m comparable sequences to match the Reference sequence X_0 in order to get the Grey relational grade from ordinal into cardinal form. The Grey relational grade will be:

$$\gamma, X_0, X_i, \square \gamma, X_0, X_j.$$

Then it can be said that γ, X_0, X_j is a Grey relational grade.

The Grey Relational Analysis of F-104 accidents

- The value of Grey relational grade of F-104's accident rate caused by personnel factor, group factor, and mechanical factor are 0.798215, 0.716485, 0.780839; which means Personnel factor. Group factor. Mechanical factor.

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2. The above value of Grey relational grade weighted by major accident, minor accident and incident became 0.791882, 0.72793, and 0.847177; which means Mechanical factor. Personnel factor. Group factor.
3. The value of detailed seven relational grades are 0.92599, 0.81242, 0.83899, 0.80263, 0.82212, 0.88172, 0.85197; the sequence line up from big to small will be as following: Skill . Leadership . Machine . Knowledge . Judgment . Rule . Communication.
4. The above detailed seven value weighted with major and minor accidents, became 0.92930, 0.80293, 0.83531, 0.80254, 0.80293, 0.82957, 0.87297; the sequence line up from big to small will be as following: Skill . Machine . Knowledge . Leadership . Rule . Judgment . Communication.

Summary of Analysis

1. From the total accident/incident point of view, the value of Grey relational grade of F-104's accident rate is personnel factor. mechanical factor, group factor, and the detailed rating is Skill . Machine . Knowledge . Judgment . Rule . Communication .Leadership.

Thus, excellent skill, well maintain aircraft, and solid professional knowledge are the vital tasks for reducing flight safety accident/incident.

2. Weighted with major and minor accidents, the value of seven relational grades showed the mechanical failure was the major cause of casualties; in the mean time poor personal quality, insufficient professional knowledge resulted in ineffective problem-solving and/or poor judgment in time of emergency which made pilot did not have enough time to eject.

3. Other than unfamiliar training courses and poor skill, mechanical failure, insufficient professional knowledge, improper leadership made them could not eliminate problems and/or get rid of dangerous situations in the shortest possible time and caused the major accidents.

4. After weighted, the relational grade of the rule-base level moving forward which showed regulation violation in airfield was one of the major factors that causing major accidents.

Conclusion

1. The major accident primary cause of F-104 fighter is mechanic factor. In the mean time, group factor learning efficiency was low which indicated mechanical failure factor (maintenance quality) and group factor (communication, judgment, leadership) affect flight safety greatly.

2. The first cause of mishap was the skill problem of pilots. The probable explanations to pilot skill problem are as following: Firstly, new pilot training, especially the leading way of the leaders when training their wingmen could have a tremendous room of improvement. Secondly, leaders and/or instructors pilot violate regulation at airfield training gave wingmen a wrongful demonstration. If these situations can be corrected, flight safety can be improved.

3. Due to the shortage of Crew Resource Management (CRM) knowledge, the CRM practical training and concept promotion did not welcome within the military organization. The consequence of CRM ignorance was flight safety accident/incident could not be decreased effectively. No matter conducting flight training or combat operation, fighter pilots should support each other and which consist of all crew such as civil and military air-traffic crew, maintenance crew, meteorological crew, etc. Other than multi-crew transportation aircraft, single-seat fighter, CRM concept and training should be introduced and implemented as well. Two F-16 single-seat fighter pilots and Boeing 747 pilots use some common resources, such as: in hardware both use radio, flight operation system, emergency equipment and auto-pilot; in software both use flight route map, operation manual, check-list, and flight record document; in live ware both of them are supported by air-traffic crew, ground crew, and other aircrew. Thus, not only civil aviators but also military pilots should take CRM training courses. The military aviation not only should develop "Cockpit Resource Management" but also "Formation Resource Management" as well because most of the time the Air Force conducts their training and operation missions under the time constrain situation. The best judgment can be made via making full use of "Formation Resource Management".

4. Military fighter formation flight, especially dense formation, should not be viewed as flight skill and discipline performance only. If the "C" of CRM stands for single-direction "command" does not have any mutual support possibility and that will generate unnecessary pressure and/or fear of mid-air coalition between pilots. Only by transforming the "C" of CRM into "cooperation" and sustaining a reasonable distance during formation flight the inner and outer situations of the cockpit can be monitored.

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